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STATE OF MINNESOTA

Office Memorandum

DEPARTMENT Health

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Water & Hazardous Materials Enforcement
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DATE: 3/9/81

FROM : Mike Convery

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SUBJECT:

For your information and review, I am enclosing a copy of Hickok's work report - Review & Evaluation of Data

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MARCH 2, 1981

ST. LOUIS PARK GROUNDWATER CONTAMINATION STUDY - REVIEW AND EVALUATION OF DATA

DOCUMENTS PERTINENT TO THE STUDY OF GROUNDWATER CONTAMINATION IN ST. LOUIS PARK, MINNESOTA, HAVE BEEN REVIEWED AND EVALUATED. AN ANNOTATED LIST OF THIRTY-FIVE DOCUMENTS HAS BEEN PREPARED AND INCLUDES THE ESSENTIAL FINDINGS, CONCLUSIONS AND RECOMMENDATIONS OF EACH DOCUMENT ALONG WITH COMMENTARY. THIS MEMORANDUM REPRESENTS COMPLETION OF TASKS 1010 AND 1020 OF THE REFERENCED PROJECT, HOWEVER, AS FURTHER PERTINENT INFORMATION BECOMES AVAILABLE IT WILL BE REVIEWED AND EVALUATED ON AN ON-GOING BASIS.

ST. LOUIS PARK GROUNDWATER CONTAMINATION STUDY

REVIEW AND EVALUATION OF DATA

Documents pertinent to the study of groundwater contamination in St. Louis Park have been reviewed and evaluated. The attached annotated list presents the essential findings, conclusions and recommendations of each document. Items listed as "comments" are statements of the reviewer, rather than the original authors.

The documents reviewed were obtained from various agencies, but the office of the Minnesota Attorney General at this time possesses all documents pertinent to the groundwater contamination in St. Louis Park. The Minnesota Department of Health and Pollution Control Agency, U.S. Geological Survey, Minnesota Geological Survey, City of St. Louis Park and U.S. Environmental Protection Agency, as well as the Attorney General's office, have been very helpful in gathering information.

The reader of the attached review should note two things. First, tables included in the review are not quoted from, and cannot be found in, the original documents. Instead, they represent either summaries of original tables, or else tabulation of information not originally presented in tabular format. Second, the review uses abbreviations heavily; the following list is included for reference:

SPECIAL TERMS:

Site - site of the former Republic Creosote works in St. Louis Park, Minnesota.

PAH - polynuclear aromatic hydrocarbons.

BaP - benzo(a)pyrene.

PdC-J - Prairie du Chien-Jordan aquifer.

C.M.St.P.&P. - Chicago, Milwaukee, St. Paul and Pacific (railroad).

COMMON ABBREVIATIONS:

N,S,E,W - compass directions.

Hwy - highway.

incl. - including.

approx. - approximately.

avg. - average.

max. - maximum.

ca. - circa (i.e., on or about, approximately).

MEASUREMENT UNITS:

gpm, mgd - flow rate, gallons per minute, million gallons daily.

ppm, ppb - mass concentration, parts per million, parts per billion.

mg/l, ug/l, ng/l - concentration (liquid), milligrams, micrograms and nanograms per liter.

ng/cu. m. - concentration (gas), nanograms per cubic meter.

kg - kilogram.

ft. - feet.

gal. - gallon.

cu. yd. - cubic yard.

GOVERNMENT BODIES:

SLP - City of St. Louis Park.

MDH - Minnesota Department of Health.

MPCA - Minnesota Pollution Control Agency.

MGS - Minnesota Geological Survey.

USGS - U.S. Geological Survey.

EPA - U.S. Environmental Protection Agency.

ANNOTATED LIST OF DOCUMENTS PERTINENT TO
STUDY OF GROUNDWATER CONTAMINATION IN ST. LOUIS PARK

1. Minnesota Department of Health (L. L. Kampo) (May 1938), "Report on Investigation of Disposal of Wastes of Republic Creosoting Company, St. Louis Park, Minnesota," 8 pp. incl. table, 3 figures.

Description: Report on MDH investigation of Site.

Findings: (1) Plant processed 16,000 gal. crude coal tar per day, producing creosote and road oil; and treated railroad ties.
(2) Waste production estimated as 6,000 gal. per week.
(3) Wastes discharged to 4-acre peat bog at S, bisected by state highway built 1936.
(4) Wells affected by tarry taste/odor:

Well	Location	Description
Municipal-1932	3/4 mile E of bog	Depth 540 ft, cased to 200 ft
Prestolite-ca. 1932	--	Depth perhaps 200 ft
Residential-approx. 5 wells	1/4 mile NE of bog	Depth perhaps 80 ft
Hedberg-Friedheim (larger of 2 wells)	1 1/4 mile E of bog	Depth extended from 280 ft (St. Peter) to 410 ft (Jordan), ca. 1936

(5) Water analyses:

Sample	Phenol	Other
Several wells	0.008-12.3 ppm	Odor-tarry, phenolic
Waste from ditch	50 ppm	Oil present

Conclusions: (1) Several wells near Site abandoned due to tarry taste.
(2) No contaminant source found, other than Republic Creosote.

Recommendations: (1) Stop waste disposal to "soil absorption."
(2) Find new disposal site.
(3) Treat wastes prior to disposal.

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2. E. A. Hickok and Associates, for City of St. Louis Park (September 1969), "Ground-Water Investigation Program at St. Louis Park, Minnesota," 20 pp. incl. 3 tables, 6 figures.

Description: Report on groundwater and Site investigation, incl. soil and water analyses.

Findings: (1) Water analyses by Hickok lab:

Sample	Date	Phenol
Municipal Wells	9/68	0.01 - 0.02 ppm (most wells in this range)
Minnehaha Creek	9/68	0.02 ppm
Drainage Ditch	9/68	>2.0 ppm

(2) Water analyses by others cited:

Sample	Date	Phenol
Municipal Wells 4,5,6	1946-48	0.007 - 0.100 ppm
Municipal Wells 3,4,6 and private wells	1968	0.002 - 0.025 ppm

(3) Groundwater flow generally to E, but cones of depression and liquid waste mounding affect local flow direction.
(4) Soil borings:

Number	Depth	Location
7 borings	13-18 ft	N edge of Site to 3,000 ft SSE of Site

(5) Soil analyses by Hickok lab:
(a) Phenol 0.01-0.03 ppm (15 min. leaching);
(b) Concentration decrease with distance from Site.
(6) St. Peter wells show highest phenol near Site, downgradient, but some also to N (municipal wells 1,2,3).
(7) Jordan wells show phenol pattern similar to St. Peter.
(8) Municipal well 6 in Jordan is 7,000 ft SE of Site but has moderately high phenol.
(9) "Numerous wells which penetrate the geologic formations above the Jordan, including the Shakopee Formation, if improperly constructed could serve as conduits for vertical migration of phenols." (p. 15).
(10) Hinckley shows traces of phenol at municipal wells 11 (100 ft from wells 1,2,3 in St. Peter) and 12 (200 ft from well 6 in Jordan), possibly due to leakage.

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Conclusions: (1) Wastes such as Republic's contain phenols.
(2) Phenols found in drift, St. Peter, Shakopee and Jordan in SLP.
(3) Phenols in SLP municipal wells exceeded U.S. Public Health Service limit (0.001 ppm).
(4) Phenols found in wells up to 8,000 ft from Site.
(5) In drift, private wells near Site mostly abandoned.
(6) Principal aquifers in SLP are Jordan, St. Peter and Hinckley.
(7) Groundwater generally to E, but "in some areas the movement is controlled by local pumping wells."
(8) Phenol anaerobic biodegradation is not fully understood.
(9) Continued investigation is needed, due to lack of geological and hydrological data in SLP.

Recommendations: (1) Prohibit untreated phenolic waste disposal.
(2) Investigate contamination extent and prevention comprehensively.
(3) Immediately initiate well, stream and storm sewer monitoring.
(4) Additional soil borings and analyses penetrating water table.
(5) Observation wells into the Jordan.
(6) Quantitative pump test in drift near Site.
(7) Removal program for highly contaminated water in drift.
(8) Remove shallow, heavily contaminated soils.
(9) Removal or control program for deep aquifers.

3. Lonnes, P. and H. Patel, Environmental Research Corp., for City of St. Louis Park (May 14, 1971), "Identification of Odorous Constituents in the Emissions from a Creosote Plant," 27 pp. incl. 17 fig.

Description: report on air and vapor chemical analyses.

Finding: Gas chromatographic and other analyses of samples from Site (crude tar vapor, stack emission, ambient air) led to tentative identification of odorous compound as 2,2-dichloroethyl mercaptan ($CHCl_2CH_2SH$).

COMMENTS: (1) Apparently, odor panel independent from this work previously determined only one major component of the odor profile.
(2) The identified compound is a two carbon, non-aromatic compound.

4. Orr-Schelen-Mayeron and Associates (W. R. Long), for City of St. Louis Park (August 6, 1973a), "Surface and Sub-Surface Ground Reclamation - Republic Creosote Site, City of St. Louis Park, Minnesota," 18 pp. incl. 2 exhibits.

Description: Report on contaminated soil remedies. (Complements reference 5.)

Findings: (1) Through contact with American Petroleum Institute, best way to handle contaminated Site soils apparently land farming.
(2) In land farming, contaminated soil is applied to land, aerated and mixed with fertilizer; microbial degradation is enhanced.

(3) Exhibit I - U of M Soils Report: (a) Soil microbes sufficiently abundant for land farming (roughly, bacterial plus actinomycetes one million, fungi 10,000 per gram soil); (b) test planting (blue grass, fescue, oats) successful except for very high phenol.
(4) Exhibit II - Soil phenol analyses by Tri-City Public Health Lab: Sampling March-April 1973 showed phenol 0.01-6.5 ppm on and S of Site; said to be lower than previous sampling.

Recommendation: Land farming of contaminated Site soils is implicitly recommended.

COMMENT: Report identified surface runoff, rather than groundwater, as major pollution problem.

5. Orr-Schelen-Mayerson and Associates (W. R. Long), for City of St. Louis Park (August 6, 1973b), "City of St. Louis Park - Feasibility Report - Public Improvement 72-43 (Republic Creosote Area Storm Sewer)," 17 pp., incl. appendix, plus 2 figs.

Description: Engineering report on Site storm drainage. (Complements reference 4.)

Finding: Found costs equal for (a) three pond system (3 ac on Site, 3 ac S of Hwy 7, 5 ac S of Lake St.), gravity outlet to Creek; and (b) two pond system (on Site and S of Lake St.), lift station and force main to Creek.

Recommendations: (1) Select system on non-cost basis.
(2) Land farm contaminated soils excavated for ponds.
(3) Divert discharge from pond N of Site (32nd and Oregon) into new system.

COMMENT: Pond N of Site previously discharged by pump to E into Bass Lake watershed, which feeds Lake Calhoun.

6. Olsen, B. M., B. A. Bloomgren and R. K. Hogberg, Minnesota Geological Survey (March 1974), "The Geology of the St. Louis Park Area," 6 pp. plus 2 appendices.

Description: Report interpreting available geological data. (Appears as Appendix B to reference 8.)

Findings: (1) Nearly all SLP subsurface data from well drillers, not geological studies.
(2) Bedrock lithology:

Unit	Thickness	Description
Platteville	0-30 ft	Surface erosional; heavily jointed (where exposed)
Glenwood	2-6 ft	Sandy shale
St. Peter	130-170 ft	Quartz sandstone (130 ft +) underlain by shale and silty s.s.
Prairie du Chien	--	Sandy dolomite

(3) Platteville surface is gently rolling plateau at 800-855 ft elev. in most of SLP.
(4) Buried valleys (or "channels" or "gorges") cut into St. Peter, as near Hwy 100 and Excelsior Blvd.
(5) Glacial lithology: (a) Till (of Grantsburg sublobe, Des Moines Lobe, Wisconsin Age) to W and N in SLP; (b) outwash (from glacial melting) throughout most of SLP; (c) swamp/marsh deposits common in ice block basins (often overlying buried valleys).
(6) Drift thickness in SLP nowhere less than 50 ft, greater in buried valleys.

COMMENTS: (1) Emphasis added in 5(c) above.
(2) Buried valley near Hwy 100 and Excelsior Blvd. not shown extending W to Louisiana Ave.

7. Sunde, G. M., for City of St. Louis Park (July 1974), "Hydrogeologic Study of the Republic Creosote Site," 42 pp., 3 tab., 8 fig., appendix.

Description: Report reviewing recent MDH well water analyses (Winter 1973-74) and other data.

Findings: (1) Surficial geology described as Des Moines Lobe (Wisconsin stage) outwash, possibly underlain by till (e.g., at 60-ft depth near Hwy 7), approx. 80 ft thick in all.
(2) Glenwood shale is often fractured continuously with Platteville, which is normally fractured.
(3) Groundwater:

Aquifer	Gradient	Head
Surficial	Slightly to S or flat	10 ft ± above St. Peter head
St. Peter	6-25 ft/mile to E	870 ft ±, or 60 ft above PdC-J head
Prairie du Chien-Jordan	Historic to E (areal recharge 3.5 inches ± per year)	
Mt. Simon-Hinckley	--	630 ft ± (rock at 78 ft elev.)

(4) St. Peter pumpage centers (non-potable private to E, municipal wells 1,2,3 to N) may increase contaminant movement downward through drift by (a) enhancing leakage through Platteville/Glenwood or (b) pulling directly from drift (many wells cased only to top of first bedrock).
(5) Prairie du Chien - Jordan wells uncased also through St. Peter include "Milwaukee Road" (near municipal wells 4 and 6) and "McCourtney Plastics" and "Lander's Gravel" (near municipal wells 7,9,10 and 15).
(6) Municipal well 1,2,3 logs show possible penetration of PdC-J.
(7) PdC-J pumping occurs in all directions from Site, but contamination from Site seems impossible at municipal wells 14 (9,000 ft NE of Site) and 8 (12,000 ft NW).
(8) Mt. Simon-Hinckley contamination possible from uncased well but not seepage.
(9) Phenol in urban runoff 0.008-0.02 mg/l (near Site but not from

Conclusions: (1) MDH found low phenol levels in SLP wells.
(2) Phenol levels "not detrimental" (no taste/odor problem).
(3) Phenol contamination of some wells not attributable to Republic (from flow analysis).
(4) Prairie du Chien-Jordan and Mt. Simon-Hinckley contamination will not spread, "as long as pumping continues."

Recommendations: (1) Multi-aquifer wells should be plugged.
(2) Site should be developed (reduce infiltration).
(3) Shallow monitoring wells should be placed, toward design of pumpout system.
(4) Other corrective measures: (a) possibly abandon municipal wells 1,2,3 in St. Peter, (b) encourage non-potable industrial use from St. Peter.

COMMENT: MDH sampling results show measurable phenol at least once in all municipal wells but one (with single analysis).

8. Minnesota Dept. of Health (September 1974), "Report on Investigation of Phenol Problem in Private and Municipal Wells in St. Louis Park, Minnesota, Hennepin County," 49 pp. incl. 2 appendices.

Description: Report on well testing and soil analyses on, and S of, Site.

Findings: (1) Determinable levels of phenol found in municipal and private wells.
(2) contamination found from drift to Red Clastics at 900-ft depth, and spatially over much of SLP.
(3) Highest phenol concentrations near Site.
(4) Soil samples in marsh S of Hwy 7: at 45 ft, black, viscous, creosote odor (and water high in phenol); at 67 ft, tar-like odor.
(5) With very low groundwater phenol (as found), expect fluctuations in concentration.
(6) Robinson Rubber Co. well (St. Peter, 2,000 ft ESE of Site) shows steady, high phenol.
(7) Intermittent phenol occurrence could be related to well pumping patterns.

Recommendations: (1) Comprehensive geohydrologic study of aquifer effects from Republic.
(2) Feasibility study of aquifer rehabilitation (or confinement).
(3) On-going epidemiological study.
(4) Groundwater monitoring of "affected area."
(5) Contingency plans (removal, treatment).

9. Orr-Schelen-Mayeron and Associates (J. A. Johnson), submitted to Minnesota Pollution Control Agency (October 8, 1974), "St. Louis Park 72-43 Supplemental Information," 128 pp. incl. 5 "supplements" (and excluding plans and specifications).

Description: Memorandum responding to MPCA questions on proposed storm drainage.

Findings: (1) Runoff volume estimated as 200 ac-ft per year.
(2) Runoff phenol concentration in ponds estimated as 1.3 mg/l (maximum possible).

COMMENT: Supplements include some 64 soil borings and correspondence with Prof. Ham (U of M) regarding land farming.

10. Minnesota Dept. of Health (ca. 1974), Analytical data from well samples in St. Louis Park, Hennepin County, 56 pp.

Description: Analytical data for wells sampled 1973-1974 in SLP.

COMMENTS: (1) Phenol analysis included for most samples, measurable in many.
(2) Highest phenol at Robinson Rubber Co., well, approx. 1.0 mg/l.

11. National Biocentrics, Inc., submitted to Minnesota Pollution Control Agency (Aug. 12, 1975), "Proposal for a Groundwater Study of the Old Republic Creosote Site in St. Louis Park," 77 pp.

Description: Technical proposal.

COMMENTS: (1) Includes background on coal tar and creosote manufacturing processes and chemical constituents.
(2) Includes background on bacterial degradation, showing specific metabolic pathways for naphthalene and phenol degradation

12. National Biocentrics, Inc., for City of St. Louis Park (April 16, 1976), "Environmental Assessment - Oak Park Village," 73 pp. incl. 9 tab., 8 fig., 3 appendices.

Description: Environmental assessment for Site development.

Findings: (1) Noted that in 1971, testing by Mellon Institute with sophisticated testing capabilities found no measurable phenol in SLP water supply.
(2) Soils on site generally 5-10 ft fill, peat or fine sand and gravel, underlain to 25-ft depth by medium or coarse sand and gravel.
(3) Soil contamination:

Location	Date	Description
S part of Site (top 2 ft) and S of Site (top and 25-ft depth)	4/71	Highest oil
S of Site	2/74	Phenol up to 90 ppm ±
S part of Site	12/74	Phenol up to 30 ppm ±

(4) Peat zone exists on Site central N-S axis.
(5) Humic acids (as in peat) solubilize DDT and could solubilize PAH.
(6) Land farming with winter wheat was done on W part of Site (ca. 1976).
(7) Runoff ponds on Site and S of Lake St. lined with 30 mil polyvinyl chloride.
(8) Runoff treatment with chlorine dioxide followed by sulfur dioxide.

(9) Runoff NPDES limits (April 1975) include:

Parameter	Limit	
Benzo(a) pyrene	0.01 mg/l	(10,000 ng/l)
Chrysene	0.01 mg/l	(10,000 ng/l)
Phenol	0.1 mg/l	
Quinone	0.4 mg/l	
Oil and Grease	15 mg/l	

Conclusions: (1) Proposed development of Site is of local significance only.
(2) Project does not have potential significant environmental effects.

Recommendation: No environmental impact statement should be required.

13. Barr Engineering Co., for Minnesota Pollution Control Agency (May 1976), "Soil and Ground Water Investigation, Coal Tar Distillation and Wood Preserving Site, St. Louis Park, Minnesota - Phase I Report," 29 pp. plus 4 tab., 40 fig., 4 appendices.

Description: Report on groundwater and Site investigation, early phase, including soil and water analyses.

Findings: (1) Soil phenol and benzene extractable high S of Hwy 7, at depth (high in granular soils overlying till layers).
(2) Soil PAH (incl. BaP and chrysene) also high S of Hwy 7 (high in sands at 32 ft and 50 ft, low in tills between and below).
(3) Groundwater phenol and benzene extractable measurable on Site and in Midco Register (Robinson Rubber Co.) well in St. Peter.
(4) Groundwater phenol and b.e. not measurable in (a) Platteville at NE, (b) drift to W, N and S, and (c) municipal wells 1,2,3 (St. Peter to N).
(5) Glenwood shale appears not to be leaky, near well field N of Site.
(6) "Measurable vertical leakage is occurring into the Jordan sandstone in" area of well field N of Site.

COMMENT: Figures show phenol and b.e. concentration contours in drift cross-sections.

14. National Biocentric, Inc., for City of St. Louis Park (June 22, 1976), "Addendum to the Oak Park Village Environmental Assessment," 4 pp.

Description: Addendum to environmental assessment for Site development. (Appears as part of reference 15.)

Finding: Due to Barr (May 1976) findings, Site development plan revised: (a) include N part of Site only, (b) easements available for well and pump placement, (c) structure footings and foundations to withstand 5-ft water table drop, and (d) contamination pocket in N part (4 ac area, 11,000 cu. yd.) to be excavated and land farmed in S part.

Recommendations: (1) No environmental impact statement should be required.
(2) Approve revised development plan.
(3) More definitive borings and chemical analyses before excavating.
(4) continue studies "to south" of soils and groundwater.

15. City of St. Louis Park, submitted to Minnesota Environmental Quality Council (June 23, 1976), "Supplemental Information - Environmental Assessment - Oak Park Village," 81 pp. incl. 6 fig. and 4 appendices, plus addendum.

Description: Report describing modified Site development plan.

Findings: (1) Storm sewer system completed spring 1976: (a) drains 300 ac (incl. 80-ac Site), (b) runoff treatment by sodium hypochlorite and chlorine, plus dechlorination, (c) pipes specially sealed from infiltration, (d) excavated soils land farmed, (e) cost $1.8 million (incl. $0.8 million for pollution control).
(2) Land farming in 1975-76 of soils excavated for pond on Site: (a) spread 1 ft thick over W part of Site (40 ac ±), (b) 3 cycles of plowing, replanting, (c) no runoff quality problems, (d) soil monitoring showed phenol "gone" and grease/oil 61% reduction (from 3,700 to 1,450 ppm).
(3) Visual soil contamination reconnaissance June 14-15, 1976, by National Biocentrics: (a) contaminated zone in NE part of Site 11,000 cu. yd., thickness 6 ft max., (b) contaminated zone in central part of Site 5,000 cu. yd., thicknes 1 ft, (c) out of 19 borings in N part of Site, all but 3 had aromatic odor.

Recommendation: Environmental assessment with additional submittals be accepted as adequate by Minn. Env. Quality Council.

16. National Biocentrics, Inc., submitted to City of St. Louis Park (July 21, 1976), "Proposal - Soil Boring and Chemical Analyses of the Northern Portion of Oak Park Village," 22 pp.

Description: Technical proposal.

COMMENT: Includes table of coal tar and creosote constituents.

17. National Biocentrics, Inc., for City of St. Louis Park (September 17, 1976), "Soil Boring and Chemical Analysis of the Northern Portion of Oak Park Village," 78 pp. incl. 3 appendices.

Description: Report of soil analyses. (Also appears as Appendix B to reference 18.)

Findings: (1) Soil analyses by National Biocentrics:

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Boring	Total Depth (ft)	PAH Presence (Infra-red Scan)	Contamination Depth (ft)	Visual	Odor
C-2	52	Yes	4.5	Yes	Heavy
			31	No	Slight
C-3	17	No	6	No	None
			16.5	No	None
C-4	12	Yes	3	No	Slight
			11	No	Slight
c-5	12	Yes	2.5	Yes	Slight
			10.5	No	None

(2) PAH (phenanthrene plus pyrene plus chrysene) for boring C-2 (NE part of Site) by National Biocentrics:

Depth (ft)	PAH (ppm, dry wt.)
4.5	770
31	1,210
52	0.64

18. National Biocentrics, Inc., for City of St. Louis Park (November 1, 1976), "Soil Contamination by Creosote Wastes - A Quantitative Physical/Chemical Analysis of the Northern Portion of the Former Republic Creosote Site," 8 pp. plus 2 appendices.

Description: Report on soil investigation of N part of Site.

Findings: (1) Infra-red scan of soil samples for PAH presence correlated with odor detection.
(2) Earth resistivity and 11 shallow auger borings used to delineate contamination.

19. City of St. Louis Park (December 2, 1976), "Development Plan, Northern Portion Oak Park Village," 19 pp. incl. 4 fig.

Description: Report on revised development plan and remedies for N part of Site.

Findings: (1) In July 1976, Minnesota Environmental Quality Council approved "Oak Park Environmental Assessment" (with supplements) and did not require environmental impact statement, conditional on review and approval by MPCA, MDH and MDNR of City's plans for:

(a) Soil borings and chemical analyses;
(b) Contaminated soil excavation, removal and treatment; and
(c) Site preparation and structure foundations.

(2) Contamination of N part of site amounts to approx. 1-2% of total contamination in area.
(3) City's plan includes:

(a) Excavating visibly contaminated soil to depth up to 8 ft, and allowing no structure where contaminant depth exceeds 8 ft;
(b) Land farming excavated material, with temporary stockpiling at S part of site, to W of runoff pond; and
(c) Structure foundations capable of withstanding groundwater fluctuations; and
(d) Utilities (water, sewer) from N of Site.

20. Barr Engineering Co., for Minnesota Pollution Control Agency (June 1977), "Soil and Ground Water Investigation, Coal Tar Distillation and Wood Preserving Site, St. Louis Park, Minnesota," 119 pp. plus 10 tab., 34 fig., 6 appendices.

Description: Final report on groundwater and Site investigation, including soil and water analyses.

Findings: (1) glacial soils strata:

(a) Upper drift - organic soils on N-S axis, outwash;
(b) Till stratum - thickness 2-5 ft, greatest under peats;
(c) Middle drift aquifer - outwash and ice contact deposits, some clay lenses, thickness 15-48 ft, avg. 20 ft; and
(d) Lower drift - complex sands, till, thickness 12-45 ft, avg. 20 ft.

(2) Buried becrock valleys (from well log data):

(a) E of Site, at Excelsior Blvd. and Hwy 100, approx. 25 ft of St. Peter eroded, with Platteville and Glenwood absent to W perhaps to 36th and Wooddale;
(b) S of Site, Platteville missing at Louisiana Ave. extension and C.M.St.P.&P. railroad but Glenwood probably present there and to S at Methodist Hospital.

(3) St. Peter sandstone "underlain by an unconformity of rather high relief" so thickness varies - basal silt - and claystone thickness 55 ft at municipal well field to N, 32-50 ft near Site (citing Olsen's M.S. thesis).

(4) Aquifer characteristics (collected from various sources, or estimated, or modified as result of hydrologic analysis):

Formation	Thickness (ft)	Permeability (cm/s)	Porosity (%)
Till Stratum	2-5	10^{-6} - 10^{-4}	--
Middle Drift Aquifer	20	10^{-3} - 5 x 10^{-2}	30
Lower Drift	20	("resistivity" 1.4 x 10^{7} sec.)	--
Platteville	0-31	--	--
Glenwood	3	10^{-8}	--
St. Peter (upper)	110	5 x 10^{-3}	30
Basal St. Peter	55	4 x 10^{-7}	20
Prairie du Chien-Jordan	244	1.6 x 10^{-2}	20
St. Lawrence, Franconia, Ironton-Galesville	--	--	--
Eau Claire	87	10^{-10}	10
Mt. Simon-Hinckley	--	3.5 x 10^{-3}	10

(5) Multi-aquifer wells (connecting drift/Platteville to St. Peter) newly found:

(a) Terry Excavating, and
(b) Midco Register.

(6) Groundwater Quality:

(a) Wetland to S of Site (between Hwy 7 and Lake St.) is area of highest phenol;
(b) At 1,000 ft E of wetland, phenol is 10 times higher in lower drift than middle drift aquifer;
(c) At wetland, settleable material in sample had specific gravity 1.02;
(d) St. Peter well near and downgradient from wetland had phenol comparable to municipal St. Peter wells 1,2,3 to N.

(7) Groundwater movement:

(a) Basal St. Peter leakage approx. 1 ft/yr (true velocity), hence flow time 55 yr + through formation;
(b) Eau Claire flow time estimated as 34,000 yr;
(c) Middle drift aquifer movement 30-150 ft/yr (gradient approx. 1 ft per 1,200 ft).

Conclusions: (1) Coal-tar derivatives detected in 90% of soil samples, especially high at S and to S of Site; PAH found at depth to S and in near-surface coal-tar waste.
(2) Groundwater movement in drift (to S and SE of Site) approx. equally lateral and downward; in Platteville mostly lateral, probably to buried valley.
(3) Groundwater contamination to S and E of Site:

Well	Location	Depth	Phenol	PAH
W13	Between Hwy 7 and Lake St.	50 ft	50 ppm	3,400 ppm = 3,400,000,000 ng/l
W17	1,500 ft ESE of Site	Drift-bedrock contact	0.3 ppm	1.7 ppm = 1,700,000 ng/l

(4) Contaminant movement in drift toward SE at 30-150 ft/yr; in Platteville toward buried valley (at Excelsior Blvd. and Hwy 100) with flow time 20-50 yr, perhaps "much less."
(5) Buried valley at Excelsior and Hwy 100 is recharge area for St. Peter.
(6) There are a number of multi-aquifer (uncased) wells in area.
(7) Phenol detected in bedrock wells under site and to N at municipal well field (incl. St. Peter, Prairie du Chien-Jordan and Mt. Simon-Hinckley).
(8) Future groundwater contamination expected to increase in St. Peter, hold steady in Mt. Simon-Hinckley.
(9) Coal-tar derivatives in drift potentially threaten underlying aquifers via:

(a) Uncased wells;
(b) Buried bedrock valley;
(c) Seepage through Glenwood;
(d) Industrial well abandonment, downgradient (formerly barriers).

(10) Control of groundwater contamination in drift is technically feasible with three pumpout wells at 15 gpm each, with peak phenol 1-3 ppm and peak PAH approx. 100 ppm.
(11) Pumpout well effluent disposal could be to sanitary sewer or runoff pond/treatment system.
(12) Excavation volume for 1 ppm phenol 700,000 cu. yd. (max. 60 ft. depth), for 1,000 ppm benzene extractable 400,000 cu. yd. (max. 30 ft. depth).

Recommendations: (1) Abandon and grout all uncased multi-aquifer wells, especially between Hwy 100, Texas Ave., Minnetonka Blvd., and Excelsior Blvd., and Minnehaha Creek.
(2) Abandon municipal St. Peter wells 1,2,3.
(3) Implement measures to halt coal-tar derivative movement in drift.
(4) Design and construct gradient control wells, first placing more wells and borings and conducting well tests.
(5) Use sanitary sewer, at least initially, for gradient control well effluent disposal.

(6) Conduct bench and pilot treatability studies.
(7) Monitor drift/Platteville groundwater and treated well effluent.
(8) Monitor St. Peter under zone of high drift contamination S of Site; if phenol exceeds 0.02 ppm implement St. Peter gradient control wells.
(9) Study public health effects of phenol in municipal water of SLP.
(10) Study buried bedrock valley at Excelsior Blvd. and Hwy 100, incl. soil borings and monitoring wells.

COMMENTS: (1) The glacial soils strata named by Barr have been essentially adopted by USGS.
(2) Excavation volumes reported are apparently in error and should be approximately four times grater, based on Figures 28 and 31 of report.

21. Minnesota Geological Survey (B. Olsen and G. Gabanski) (Oct. 17, 1977), Letter to Mr. D. L. Wikre, Minnesota Pollution Control Agency, 4 pp. plus figures and attachments.

Description: Letter reviewing Barr phase II report (reference 20).

Findings: (1) Buried valley (radiating from Excelsior Blvd. and Hwy 100) said by MGS to have greater extent of missing Glenwood shale than Barr report shows (additional boring and well log data cited):

(a) Valley branch to S of Site - Glenwood missing to C.M.St.P.&P. railroad and Louisiana Ave. Extension (4,000 ft further W and N than in Barr report);
(b) Branch to E - extends N to C.M.St.P.&P. railraod near Hwy 100 (1,500 ft further N than in Barr).

(2) Groundwater movement in St. Peter said by MGS to be greater toward N than Barr shows due to greater recharge at buried valley to S of Site (thus explaining contamination of municipal St. Peter wells 1,2,3 to N).

Recommendation: Additional borings in both branches of buried valley.

COMMENT: Recent borings at valley to S of Site have still not defined valley unambiguously.

22. Minnesota Pollution Control Agency (Oct. 25, 1977), "Consideration of Recommendations on the Soil and Ground Water Problem, St. Louis Park, Minnesota," 17 pp. plus 7 fig.

Description: Memorandum reviewing contamination problem and Barr reports (references 13 and 20).

Finding: Barr phase I finding of high contamination at 50-60 ft depth caused focus to shift in phase II from excavation to groundwater movement control and description of groundwater hydrology and quality in bedrock as well as drift.

Conclusions: Follow those in Barr phase II report, omitting Barr's conclusions 1, 10, 11 and 12.

Recommendations: (1) MPCA staff recommendations follow those in Barr phase II except:

(a) MPCA omits Barr's 6 (bench and pilot treatment studies) and 9 (health effects studies);
(b) MPCA emphasizes need to study buried valley to S of Site; and
(c) MPCA recommends pretreatment of gradient control well effluent, prior to discharge to sanitary sewer.

(2) MPCA staff further recommends City of SLP carry out studies and correctives, and MPCA enforce this.

23. Minnesota Dept. of Health (October 1977), "Assessment of Possible Human Health Effects Resulting from the Contamination of the Former Republic Creosote Site," (Draft), 60 pp.

Description: Report assessing cancer risk from contamination originating from Site.

Findings: (1) Information gaps noted:

(a) Contamination extent;
(b) Contaminant movement;
(c) Population group affected;
(d) Airborne human contact;
(e) External (skin) human contact;
(f) PAH content of drinking water (only phenol data available as of Oct. 1977).

(2) PAH, although "quite insoluble," can solubilize as colloidals ("micelles"), enhanced by organic detergents and organic and inorganic salts.
(3) PAH subject to biomagnification, accumulation in fatty tissue.
(4) PAH equilibrium vapor pressure varies with molecular size and temperature:

PAH	"EVC" (ng/cu. m.) Summer	Winter
Pyrene (4 rings)	140,000	580
Coronene (7 rings)	0.06	2×10^{-5}

(5) PAH degrades by photo-oxidation readily in atmosphere, also in surface waters.
(6) PAH formation mostly from incomplete combustion of organic matter.
(7) PAH sources:

(a) Industrial - coke, coal-tar, petroleum products, coal burning, refuse burning;
(b) Transportation - fuel combustion, tires, asphalt;
(c) Food - coffee, meat, tobacco.

(8) PAH levels in environment (from various studies):

Medium	Benzopyrene	PAH (undifferentiated)
AIR:		
Urban	<1-60 ng/cu. m.	--
Rural	0.01 - 2 ng/cu. m.	--
At coal-tar roofing area	6,000,000 ng/cu. m.	--
SOIL:		
"Background"	1 - 10 ppb	--
Urban	100 - 350 ppb	--
At oil refinery	200,000 ppb	--
OCEAN:	"ubiquitous"	--
FRESHWATER:		
"Natural"	<0.01 - 0.1 ng/l	--
Rivers	1 - 150 ng/l	120 - 3,100 ng/l ("carcinogenic PAH" 10 - 1,300 ng/l)
GROUNDWATER:		
"Uncontaminated"	("carcinogenic PAH" 1 - 10 ng/l)	
DRINKING WATER:		
"Found up to"	--	100 ng/l
"In general less than"	--	25 ng/l

(9) PAH levels in materials (from various studies):

Material	Benzopyrene	PAH (sum of spec. concs.)
CREOSOTE	--	Approx. 10%
COAL TAR	0.4 - 3%	Approx. 5%
SOOT	0.2%	--

(Note: 1% = 10,000,000 ppb.)

(10) Animal carcinogenesis studies (various):

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Substance	Carcinogenesis Demonstrated	Species
Coal tar	Skin, soft tissue	--
Creosote	Skin	--
Benzopyrene	Oral, skin, breathing	Many, incl. some primates
Benz(a)anthracene	Oral, injection	Mice
Dibenz(a,h)anthracene	Oral, skin, injection	Many

(11) Occupational cancer:

(a) Skin cancer among chimney sweeps and coal tar and pitch industries recognized by British "Workmen's Compensation Act" of 1907;
(b) Coal tar roofers, coke oven workers - elevated death rates from lung and other cancer.

(12) Tumor promoters and co-carcinogens are present in creosote and coal tar.
(13) Latent (or "induction") period found in animals to be inversely related to dose (and probably so for humans).
(14) Max. acceptable drinking water concentration of benzopyrene provisionally determined as 0.31 ng/l, based on extrapolation from animal studies.
(15) Studies needed for complete risk assessment:
(a) Municipal well water PAH:
(b) Airborne PAH:
(c) Epidemiology;
(d) Geohydrology of buried valleys to S and E of Site;
(e) Geohydrology of Platteville limestone;
(f) Contamination of old SLP well #1 and Robinson Rubber Co. well;
(g) Coal tar constituents' solubility and sorption properties.

Conclusion: "The assessment...supports the conclusion that there exists a significant potential impact on human health resulting from the contamination of the Republic Creosote site."

Recommendations: (1) Perform studies above.
(2) Well abandonment as per Barr phase II, except study Robinson Rubber Co. well before abandoning.
(3) Pumpout/barrier well system for drift, Platteville, and "any deeper aquifer which the geohydrologic studies show to be significantly contaminated."
(4) Remove contaminated soil, if geohydrologic studies show "no reasonable assurance" of waste not spreading beyond control of well system.
(5) Prohibit construction on site, if it will interfere with future correctives.
(6) If "significant human exposures" from ambient air found, then re-evaluate site development and perform "all feasible measures" to reduce human air-borne exposure.

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24. Serco Laboratories, for City of St. Louis Park (March 1978), "results of Laboratory Analysis, St. Louis Park Soil Borings," 5 pp. incl. attachments.

Description: Report on soil chemical analyses from borings S of Site.

Findings: (1) For 6 borings along Louisiana extension, Lake to Oxford Streets, benzene extractable 14-34,000 mg/kg and phenolics <0.2 - 4.6 mg/kg (dry weight).
(2) Peat "control sample" (from off Site) benzene extractables 22,300 mg/kg (dry wt.).

25. Gray, D. G. and W. H. Scruton, Minnesota Dept. of Health (November 1978), "Health Implications of Polynuclear Aromatic Hydrocarbons in St. Louis Park Drinking Water," 25 pp. incl. tab., 2 fig.

Description: Report on PAH monitoring, May-August 1978, of municipal and other wells in area (SLP, Edina and Robbinsdale) and outside area (Fridley and White Bear Lake) and surface municipal water (Minneapolis and St. Paul); and risk assessment.

Findings: (1) PAH measurable in SLP wells 10 and 15, 7 and 9, and 14 (ranked most to least severe), all in Prairie du Chien - Jordan.
(2) Groundwater flow apparent to N from Site.
(3) Benzo(a)pyrene not detected in most samples, present near detection limit (approx. 1 ng/l) in a few samples.
(4) PAH dietary intake (from various studies):

Food	Ingested ug PAH/day		
	Pyrene	Fluoranthene	Anthracene
Steak	2.1	2.6	0.04
Other Solid Foods	1.2	1.2	0.06
Coffee	0.1	--	--
TOTALS	3.4	3.8	0.1

(5) PAH intake by users of SLP wells 10 and 15 (based on max. concentrations measured, and consumption 2 liters/day):

	Ingested ug PAH/day		
	Pyrene	Fluoranthene	Anthracene
From Wells 10 & 15	2.4	0.9	0.5

(6) PAH exposure from SLP drinking water "represents a potential health hazard," since dietary intake estimate could err by factor of 10 either high or low.

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Conclusions: (1) Potential health hazard indicated for SLP wells 10 and 15, 7 and 9.
(2) SLP well 14 contamination not severe enough to limit use.
(3) Other wells not contaminated with PAH.
(4) Geographic PAH distribution suggests Republic Site is source and there is groundwater movement to N.

Recommendations: (1) Treat or else halt usage of SLP wells 10 and 15, 7 and 9.
(2) Monitor PAH in additional wells to N, W and E of Site.
(3) Monitor PAH in SLP water distribution system.
(4) Improve analytical capabilities for benzo(a)pyrene and other PAH.

COMMENT: More recent MDH analyses show benzo(a)pyrene up to approx. 30-40 ng/l in SLP wells 10 and 15.

26. Soil boring logs and PAH analyses along Louisiana Avenue extension (ca. 1978), 43 pp., incl. logs by Minnesota Dept. of Health, Soil Exploration and Braun Engineering.

Description: Brief write-up with soil PAH analyses accompanying soil boring logs along proposed Louisiana Ave. extension (Lake to Oxford Streets).

Findings: (1) Independent logs by MDH and Soil Exploration both found:

(a) Visual and odor contamination near Lake St. (near Site and wetland to S of Site);
(b) "Clean" appearance near Oxford St. (2,000 ft S of wetland).

(2) Selected PAH soil analyses:

			PAH Concentration (ug/kg)			
Boring	Location	Depth (ft)	Fluor-anthene	Benzo(a) pyrene	Benzo (g,h,i) perylene	o-Phenylene-pyrene
1	Near Lake St.	12-13.5	190,000	19,100	--	7,240
6	Near Oxford St.	5-26.5	2.0-.23	<0.7	<2.8	<0.9

(3) Additional 18-19 borings and logs by Braun Engineering in same area indicate:

(a) Chemical odor in all but 2-3 borings;
(b) Visible creosote at 23-26 ft depth found in boring ST-8, to S of Lake St.

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COMMENT: Braun's borings ST-53 and ST-64 near C.M.St.P.&P. railroad (in vicinity of buried valley to S of Site) encounter as first competent bedrock, light greenish or green-white sandstone, very dense, at 84 and 98 ft depth, respectively.

27. City of St. Louis Park (January 1980), "Proposed Louisiana Avenue Interim Solution (Oxford St. to Walker St.)," 17 pp. incl. appendix.

Description: Report on proposed road construction S of Site.

28. City of St. Louis Park (February 19, 1980), "Louisiana Avenue Alternatives, Oxford Street to Lake Street," 5 pp. incl. figs.

Description: Report giving variations on proposed road construction S of Site.

29. United States of America (U.S. Environmental Protection Agency Administrator) (September 3, 1980), complaint (civil action) and prayers for relief against Reilly Tar & Chemical Corp., Housing and Redevelopment Authority of St. Louis Park, Oak Park Village Associates, Rustic Oaks Condominium, Inc., and Philip's Investment Co., 10 pp.

Description: Federal court complaint by EPA and prayers for relief.

COMMENTS: (1) Alleges Reilly Tar has and is contributing to disposal of hazardous waste "upon and into the ground and water on and beneath the Reilly Tar site" - and this is "presenting an imminent and substantial endangerment to health and the environment" and is "public nuisance."
(2) Asks court to require Reilly to pay for cleanup and carry it out, and post performance bond.

30. State of Minnesota (Attorney General Warren Spannaus, Department of Health, Pollution Control Agency). (Sept. 4, 1980), motion to intervene in civil action of U.S.A. vs. Reilly Tar & Chemical Corp. et. al., 2 pp.

Description: Federal court motion by State to intervene as "party plaintiff."

31. State of Minnesota (Attorney General Warren Spannaus, Dept. of Health, Pollution Control Agency) (Sept. 4, 1980), complaint in intervention of State of Minnesota in civil action of U.S.A. vs. Reilly Tar & Chemical Corp. et. al., 9 pp.

Description: Federal court complaint in intervention by State and prayers for relief.

COMMENT: Incorporates or closely follows EPA's allegations and prayers, plus some additional items.

32. State of Minnesota (Attorney General Warren Spannaus, Dept. of Health, Pollution Control Agency), statement of points and authorities in support of motion to intervene in civil action of U.S.A. vs. Reilly Tar & Chemical Corp. et. al., 17 pp. plus attachment.

Description: Federal court statement of case and argument by State.

COMMENT: Gives history of Reilly's operation and State's actions, and argues why State should be allowed to intervene.

33. Minnesota Dept. of Health (Mike Convery) (ca. 1980), Table of basic well information, 11 pp.

Description: Table of basic well data.

COMMENTS: (1) Mostly summarizes reference 35's Table 1, but in addition includes:

(a) Water chemistry data availability; and
(b) Lab sample numbers for abandoned wells.

(2) List of wells differs slightly from Table 1 in reference 35.

34. Minnesota Dept. of Health (ca. 1980), Municipal well analyses for PAH compounds, 162 pp.

Description: Tables of well polynuclear aromatic hydrocarbon analyses by MDH for St. Louis Park vicinity, 1979-81.

COMMENTS: (1) Municipalities included:

(a) St. Louis Park,
(b) Edina,
(c) Robbinsdale,
(d) Hopkins,
(e) Minnetonka,
(f) Richfield,
(g) Bloomington.

(2) Several residential and other private wells also included.
(3) PAH measured included 11-18 species in 1979 and 19-20 species in 1980-81.
(4) PAH detected in all wells sampled except Richfield municipal wells 2 and 4 (at least at low level for at least one PAH species).

35. Hult, M. F. and M. E. Schoenberg, U.S. Geological Survey (January 1981), "Preliminary Evaluation of Ground-Water Contamination by Coal-Tar Derivatives, St. Louis Park Area, Minnesota," 76 pp. incl. 4 tab. and 18 fig., plus 6 plates.

Description: Report on groundwater contamination in SLP area, incl. geology, groundwater flow and contaminant transport.

Findings: (1) Following discovery of tarry taste/odor in old SLP well 1 in 1932, McCarthy (well driller) reported in 1933 "several old wells" at Site used "to drain creosote."
(2) Water use in 1976 (summary of Table 3):

User	Billions of Gallons: Prairie du Chien-Jordan	Mt. Simon-Hinckley	St. Peter	Total	Average (mgd)
INDUSTRIAL	0.47	--	0.07	0.59	1.47
SLP MUNICIPAL	1.88	0.53	0.13	2.53	6.92
EDINA MUN.	2.68	0.39	--	3.07	8.40
HOPKINS MUN.	0.91	--	--	0.91	2.50
TOTALS	5.94	0.91	0.19	7.04	19.30

(NOTE: Some totals do not talley due to round off.)

(3) Prairie du Chien-Jordan aquifer:

(a) Regional gradient to E approx. 10 ft/mile;
(b) Seasonal head variation 7 ft ± near Site;
(c) Weekly cyclic head variation 2 ft ± at old SLP well 1 (4,000 ft E of Site);
(d) Small vertical gradient observed by Reeder et al (1976); and
(e) Supplies 75-85% of groundwater use in area.

(4) Mt. Simon-Hinckley aquifer supplies 15% ± of groundwater use in area, and local cones of depression in SLP and Edina might intersect to form larger piezometric "low."
(5) "Hinckley" well (W23) on Site:

(a) Depth originally (1917) 909 ft, now (1979) 595 ft with contaminated material below;
(b) Injection of 150 gpm from St. Peter to PdC-J observed;
(c) St. Peter head shows depression (nearby gradient 3-5 ft/1,000 ft in 1978-79), PdC-J impression (approx. 16 ft/1,000 ft nearby, August 1977) in W23 vicinity.

(6) Other wells injecting to PdC-J:

Contaminated: Well	Location	Apparently Not Contaminated: Well	Location
W50-Prestolite	SE of Site 2,000 ft	W47-Burdick Grain	ENE of Site 10,000 ft
W114-Hedberg-Friedheim	E of Site 6,000 ft	W69-Wolfe Lake	E of Site 7,000 ft

(7) Middle drift aquifer confined between till, lake clay (above) and basal drift complex (below), with vertical head gradient appreciable in basal, very slight in middle drift.
(8) Phenol in groundwater (25 wells in drift, Platteville and St. Peter sampled March-April 1979):

Well(s)	Phenol (ug/l)
W13-Drift at wetland to S of Site	27,000-81,000 = 27-81 ppm
Drift - 5 wells	20-240 = 0.02-0.24 ppm
Platteville - 4 wells	10-73 = 0.01-0.073 ppm
St. Peter - 1 well	13 = 0.013 ppm

(9) Benzo(a)pyrene found in only two wells:

Well	BaP (ng/l)
W6-Drift on Site	>100,000
W11-Drift, 1,500 ft ESE of Site	>100

(10) PAH (besides BaP) found in 5 drift and 6 Platteville wells.
(11) Organic carbon - in general <10% accounted for by measured species.
(12) Anomalous pumping test drawdown curves for drift wells W6 (on site) and W13 (S of Site) perhaps resulted from two-phase (hydrocarbon and aqueous) flow.
(13) Solubilies in water (selected):

Compound	Aqueous Solubility (ng/l)
Chrysene (4 rings)	2,000
Benzo(a)pyrene (5 rings)	6,000
Benzene (1 ring)	4×10^8
Phenol (1 ring, polar)	2×10^{10}

(14) Micelles ("small inclusions of hydrocarbon fluid phase"), if present, could form two-phase flow at "stratigraphic traps" (e.g. at buried valleys).
(15) Coal tar derivates introduced to groundwater by:

(a) Spills, infiltration (through unsaturated soil);
(b) Pond recharge (wetland, pond to S of Site in contact with water table);
(c) Wells (incl. W23 - "Hinckley" well on Site - where spill believed in 1930, and possibly others).

(16) NaOH (sodium hydroxide) discharged formerly in wastewater, and groundwater ratio Na:Cl locally approx. 2:1 (cf. road salt <1:1).
(17) DOC (dissolved organic carbon) "natural" groundwater levels apparently 1-3 mg/l.
(18) Nitrogen in groundwater enters area from W as nitrate, appears in contaminated area mostly as ammonia (total N approx. 5 mg/l).
(19) Preferential movement of more soluble compounds:

Well	Aquifer	Location	Ratio BaP:Phenol
W6	Drift	On Site	Approx. 1:1
W101	Platteville	E of Site 4,000 ft	Approx. 1:1,000

(Note: Phenol solubility approx. 10^7 times BaP's.)

(20) Drift groundwater at S and to S of Site most severely contaminated.
(21) Hydrocarbon fluid phase in drift moves downward relative to aqueous phase.
(22) Buried valleys to S and E of Site expose St. Peter sandstone.
(23) Contaminants moved at least 4,000 ft to buried valley to E of Site.
(24) TOC (total organic carbon) in "source fluid" 6,000 mg/l; at buried valley to E, groundwater DOC = 2 mg/l.
(25) Contaminant pattern in bedrock aquifers is complex.
(26) Multi-aquifer wells in area number at least 25.
(27) Downward flow of 20-150 gpm observed in 5 of these wells (4 wells with observed contamination).
(28) Prairie du Chien contaminant transport rapid due to high transmissivity, low effective porosity (solution channels).
(29) Prairie du Chien-Jordan gradient locally controlled by pumpage and multi-aquifer well injection.
(30) PdC-J wells up to 2 miles N of Site found contaminated in 1978.
(31) PdC-J water levels August 1977 also indicated movement to N.
(32) Shutdown of municipal PdC-J wells since 1978 possibly altered contaminant transport.